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GB 2215079 A EP 0371675 A2 US 4950046 A

(58) Field of search
UK CL (Edition L) G2J JGDB JGEC
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(54) **Tapping into optical waveguides**

(57) A method of tapping light signals from an evanescence field surrounding an optical waveguide clad with elastically deformable encapsulating material 32 (eg silicone), with the aid of a light conducting probe 35 which includes an optical fiber having a free fiber end is effected without removing encapsulating material and without breaking the optical waveguide by inserting the fiber end of the probe down towards the encapsulated optical waveguide, pressing the fiber end of the probe into the encapsulating material while deforming the material elastically to the extent permitted by the mechanical properties of the material; and angling the fiber end of the probe to the optical waveguide, so that a part of the light signal in the waveguide is taken up in the light conducting probe. The waveguide may be a polyimide film guide 30 on a silica layer 40 on an Si base 21, or may be an optic fibre (Fig. 4).

Fig. 2

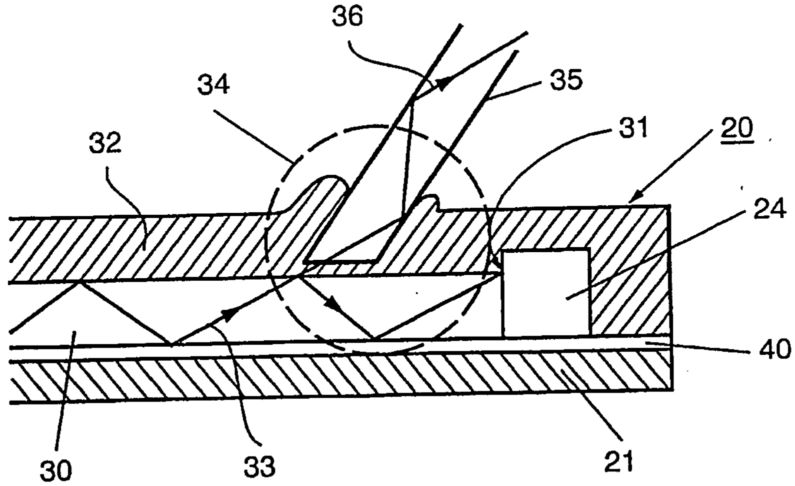

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Fig. 4

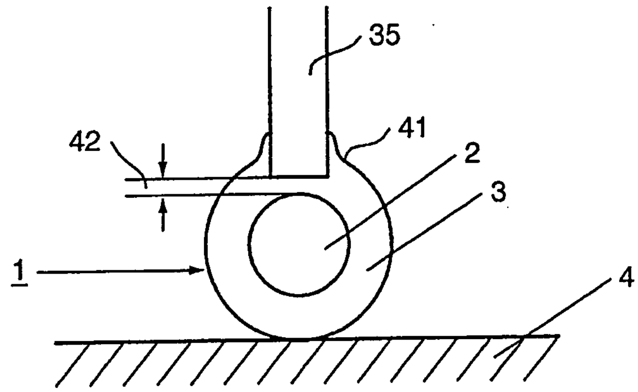


Fig. 1

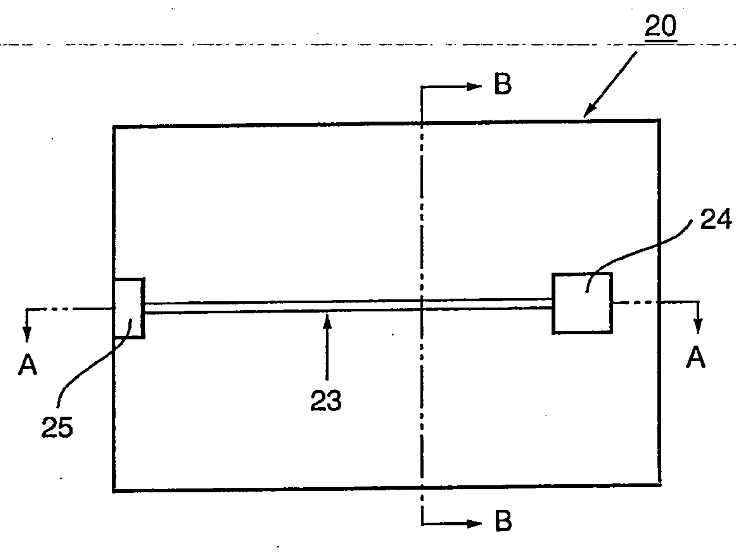


Fig. 2

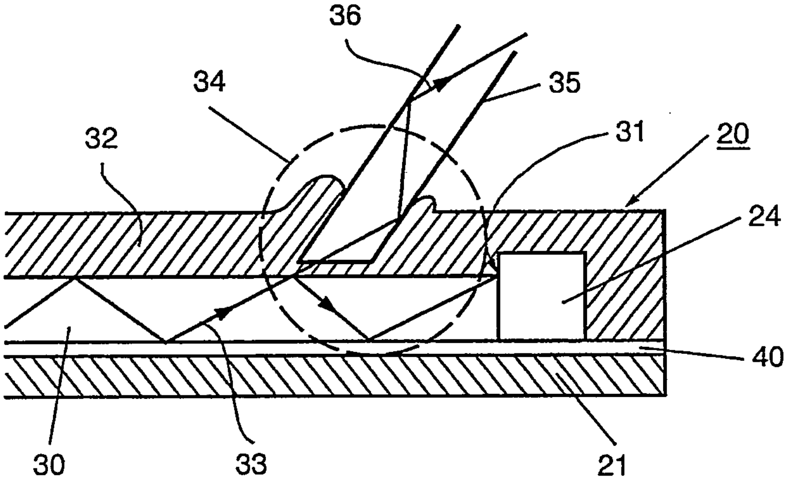
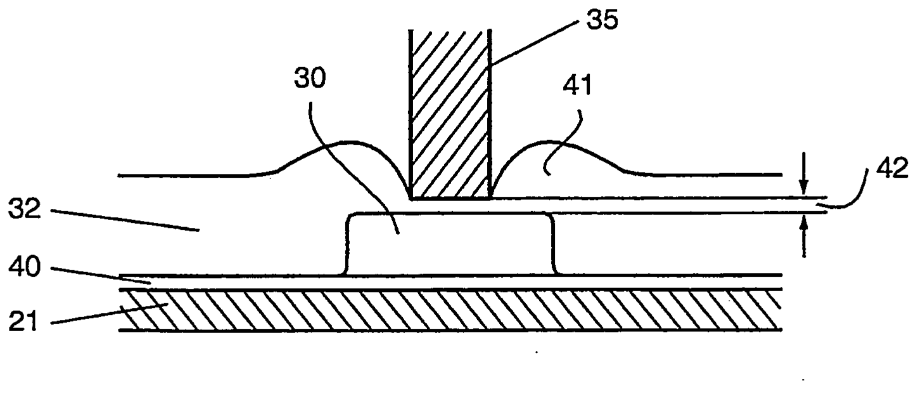


Fig. 3



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A METHOD OF TAPPING LIGHT SIGNALS FROM OPTICAL WAVEGUIDES

TECHNICAL FIELD

The present invention relates to a method of tapping light signals from an evanescence field surrounding an optical waveguide which is clad with an encapsulating material, with the aid of a light conducting probe which includes an optical fiber having a free end, wherein tapping of the light signals is effected without stripping the encapsulating material or without breaking the waveguide, and wherein tapping of said light signals is effected with a minimized damping loss.

BACKGROUND ART

In present day fiberoptic communication fields, and then in particular within the telecommunication field, it is desirable to be able to tap light signals in order to ascertain the traffic status of the optical fiber. At present, the light signals are tapped on the fiber with the aid of a permanently attached tapping device. The fiber is comprised of a light conducting core and a cladding. In order to make the light signal accessible to the tapping device, either the cladding is removed at the tapping site or the fiber is bent. The tapping device functions to tap the light signal from the core through its evanescence field.

U.S. Patent No. 3 982 123 discloses two methods of tapping a light signal from an optical fiber without requiring the fiber to be broken. The inventive concept of this patent is to look into the fiber so as to ascertain its traffic status, and signal tapping can be effected anywhere whatsoever without disturbing the traffic. This is achieved by placing the tapping device, which in this case is comprised of a material which incorporates a photo-detector, on a light conducting core or on the fiber so that tapping of light signals can be effected. The optical fiber is comprised of a core that has low optical losses and cladding which has a lower refractive index than the core.

A first method described in the patent involves removing all, or practically all of the cladding material from the fiber. The detector is then placed securely on the light conducting core, the stripped region of which must be at least three times the wave-length in the optical fiber.

A second method of tapping light signals is to bend the optical fiber without removing the cladding material. This enables the light signals to be extracted through the cladding and captured by a photodetector. Tapping is effected permanently in both cases.

U.S. Pat. No. US 4 784 452 describes a method in which tapping is effected with the aid of a tapping device placed on an optical fiber. This fiber is comprised of a light conducting core and at least one cladding material. The tapping device, a probe, is an optical fiber of the same type as the fiber from which the signals are tapped. This probe has a free end which includes a light conducting core. In order to tap light signals from the fiber, it is necessary to remove the cladding so as to expose the core. The probe is used at this exposed region, with the free end of the probe placed against the bared part of the fiber. In order to obtain the best possible tapping effect, it is necessary to adapt the angle defined by the probe axis and the fiber axis. A coupling medium connects the region at the probe and the bared part of the fiber and conducts light signals from the bared part of the fiber to the probe. The coupling medium, which is a solid and hard material, fixes the probe in relation to the fiber.

Various experiments have shown that the light conducting core may be comprised of polyimide. In the article "Dependence of Precursor Chemistry and Curing Conditions on Optical Loss Characteristics of Polyimide Wageguides" by C.P. Chien and K.K. Chakravorty at Boeing Aerospace and Electronics, Seattle, USA, SPIE vol 1323, Optical Thin Films III, New developments (1990), it is disclosed that polyimide is a good material for the optical fiber core. Polyimide has good thermal stability and a dielectric index of 3.5, which is compatible with other IC-materials. The material functions well as a light transmitter, such as in optoelectric

circuits in GH frequency range. The advantage of polyimide is that when manufacturing cores, the cores can be packed tightly together. Additional polyimide data is that it has a refractive index of 1.6 (1.58-1.62) and optical losses in the core of about 1 dB/cm when exposed to ultraviolet light.

Experiments have been carried out with a silicone elastomer as an index matching medium for the light conductive core. The article "Index Matching Elastomers for Fiber Optics" by Robert W. Filas, B.H. Johnson and C.P. Wong at AT&T Bell Laboratories, N.J. USA in the magazine IEEE, Proc. Electron. Compon. Cont., 39th, 486-9, disclose that silicone elastomers are good core index matching materials. Copolymer reflection as a function of the diphenyl concentration and temperature is obtained by measuring the reflection strength of a single mode waveguide whose core has been encapsulated in an elastomer. It is possible to obtain the same refractive index on a silicone rubber material as the refractive index of the core. The silicone rubber can be used as an interface between different components. Another method is to use the silicone rubber as protection against moisture and dust, for instance.

At present, air is used as the refractive medium to the light conducting core of the lightwave conductor. Air has a much lower refractive index than polyimide. The refractive index of air is 1, whereas the refractive index of the polyimide is 1.6 and the refractive index of the silicone rubber is 1.5.

One drawback with the earlier known solutions is that light signals are tapped from optical fibers with the aid of permanently attached devices. This means that light signals are tapped from the fiber at a specific place thereon at which cladding has been removed. The earlier solutions are encumbered with a number of additional drawbacks. One of these drawbacks is that light signals can only be tapped on fiber waveguides and that it is necessary to remove cladding from the place at which tapping shall take place. The tapping device must be placed firmly on the optical fiber at

that place from which the cladding has been removed. Tapping in permanent branches results in excessively high losses.

SUMMARY OF THE INVENTION

The object of the present invention is to eliminate the drawbacks that are encountered with earlier known methods for tapping light signals from optical fibers.

The invention relates to a method of tapping a light signal with the aid of a light conducting probe directly on an optical waveguide which is encapsulated in an elastic material. The light signal tapping method can be carried out on two types of waveguide. In one case, the method can be applied on a light waveguide which lies on a substrate, and in the other case on an optical fiber. The method is carried out by inserting the probe into direct contact with the light conducting core of a waveguide, so as to extract light signals from the evanescence field of the core without needing to remove encapsulating material or to bend the waveguide in order to tap the light signals. The probe includes an optical fiber which is of the same type as the fiber from where light signals are tapped. The probe fiber has a free fiber end.

The method is as follows:
In a first step, the fiber end of the light conducting probe is pressed down towards the encapsulated optical waveguide. In a second step, the fiber end of the probe is pressed into the encapsulating material 32 while elastically deforming said material to an extent permitted by the elastic properties of the material or so that the residual deformation, yield, does not become permanent. In a final step, the fiber end of the probe is angled to the optical waveguide 23, so that a part of the light signal will be taken up by the probe. The probe is angled so as to tap a given light signal. If the angle is changed, another light signal is obtained in the probe.

It should be noted that the fiber end of the light conducting probe is equally as wide as the optical waveguide, so as to obtain the best possible tapping. Furthermore, the probe is made from the same material as the light conducting core or from a material which has an equally as high or a higher refractive index.

The method also enables the light conducting probe to be fixed permanently to the optical waveguide, if so desired. Upon completion of the light signal tapping operation, the probe is removed without leaving a trace of its earlier presence. When tapping light signals from light waveguides, no further measures are required to enable tapping to take place.

Prior to carrying out the first method step on the optical fiber, the fiber must be placed on a hard supporting surface in order that tapping can take place. When the fiber is too flexible, it is impossible to insert a probe onto the fiber without first placing the fiber on a hard supporting surface.

The invention provides the advantage that light signals can be tapped without needing to fix the tapping device permanently at a given tapping site on the optical waveguide. Another advantage is that it is possible to tap light from the light waveguide when the waveguide is seated firmly on the substrate. Light signals have not previously been tapped from substrate mounted light waveguides. Thus, it will be seen that light signals can be readily tapped from such a system. Further advantages lie in the fact that tapping can be carried out temporarily if so desired, and that the elastic encapsulation protects against external environmental influences, such as dust, air and humidity, during a light tapping process.

Further objects of the invention and advantages afforded thereby will be evident from the preferred embodiments described below with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1-3 illustrate a first embodiment of the invention and Figure 4 illustrates a second embodiment.
Figure 1 is a top view of a light waveguide mounted on a silicon disc.
Figure 2 is an enlarged cross-sectional view of part of the light waveguide mounted on the silicon disc, taken on the line A-A in Figure 1, and illustrates a method of tapping light signals from the light waveguide with the aid of a light conducting probe;
Figure 3 is an enlarged cross-sectional view of a part of the lightwave conductor mounted on the silicon disc, taken on the line B-B in Figure 1, and shows a method of tapping light signals from the light waveguide with the aid of a light conducting probe; and
Figure 4 is a sectional view of an optic fiber and illustrates a method of tapping light signal from the optical fiber with the aid of a light conducting probe.

BEST MODES OF CARRYING OUT THE INVENTION

The Figures of the accompanying drawings are not drawn to scale and solely show those parts required to obtain an understanding of the inventive concept.

A first embodiment is illustrated in Figures 1-3.

Figure 1 illustrates an arrangement 20 which is comprised of a substrate 21, a connecting device 25, a light waveguide 23 and an optical component 24 which emits or receives light.

Figure 2 is a sectional view of the device 20 illustrated in Figure 1, said view being taken on the line A-A in Figure 1 on the optical component 24. The substrate 21 has applied thereto a very thin layer 40 which is intended to function as a refractive medium to a light conducting core 30. A very narrow gap 31 is found between one end of the core 30 and the component 24. The connecting device 25 is connected directly to the other end of the core 30. The component 24 and the core 30 are covered with an elastic encap-

sulating material 32. The broken line circle 34 illustrates a light conducting probe 35 which is pressed against the encapsulating material 32 and which taps a light signal 33 from the core 30. The probe 35 takes up an evanescence field which couples the light signal 33 from the core 30. The light signal 33 taken from the core 30 by the probe 35 forms a light signal 36 which corresponds to the light signal 33 but which is very much leaner in energy.

Figure 3 is an enlarged cross-sectional view of the light waveguide 33 taken on the B-B in Figure 1. Figure 3 illustrates the light waveguide 23, which is comprised of the light conducting core 30, the thin layer 40 on the substrate 21 and the encapsulating material 32. The refractive index of the encapsulating material is lower than the refractive index of the core 30. The layer 40 lies on the substrate 21 and the core 30 lies on top of the layer 40. The encapsulating material 32 covers everything which lies on the substrate 21. When the light conducting probe 35 is pressed down towards the core 30, a temporary deformation 41 is formed in the encapsulating material 32. When the probe 35 is pressed down to its maximum position in order to achieve an optimum tap, a very narrow gap 42 is formed between the probe 35 and the core 30.

The substrate 21 illustrated in Figure 1 is a silicon disc of the kind from which semiconductors are normally comprised. The substrate 21 may have several light waveguides 23, components 24 and connecting devices 25 mounted thereon. The substrate 21 may also be comprised of circuit board material, a glass material or any type of material whatsoever provided that the substrate 21 will have a lower refractive index than the core 30. It is important that damping in the core 30 is as low as possible .

In the embodiment illustrated in Figures 2 and 3, the light waveguide 23 is comprised of three parts. These parts are the thin layer 40 applied to the substrate 21, the core 30 and the encapsulating material 32. When the substrate 21 is made of silicon, the layer 40 is comprised of silicon dioxide. It is necessary that

the refractive index of the layer 40 is lower than the refractive index of the core 30, in order not to conduct light therefrom. In the case of the Figure 2 and 3 illustrations, the light conducting core 30 is a multimode core, although it may also be produced as a single mode core.

The encapsulating material 32 is a silicone elastomer, for instance silicone rubber. The encapsulating material is intended to enable light signals to be tapped from the core 30. Since the encapsulating material is elastic, the probe 35 can be pressed down towards the core 30. The silicone rubber is optically conductive. The encapsulating material 32 can be applied to the substrate 21 and the components 24 and 25 mounted thereon while the material is still moldable, whereafter the material is allowed to harden and therewith become elastic.

The aforedescribed arrangement 20 is used for tapping light signals 33 with the light conducting probe 35 inserted directly onto the optical waveguide. By inserting the probe 35 down through the elastic encapsulating material, it is possible to come so close to the core 30 as to enable the evanescence field around the core 30 to be taken up. This results in practically no losses in the core 30. It is important that the probe 35 is not inserted too far into the encapsulating material, because the deformation 41 therein may then be permanent. On the other hand, if the probe 35 is not pressed sufficiently far into the encapsulating material 32, the probe will be unable to take-up the evanescence field. The distance between the probe 35 and the core 30 must be of the correct order of magnitude, less than μm. In order to obtain the same distance at each tapping operation, a distance measuring instrument can be used to obtain the correct distance.

The method includes the steps of:
pressing the fiber end of the light conducting probe down towards the encapsulated optical waveguide;
pressing the fiber end of the probe 35 into the encapsulating material 32 while elastically deforming 41 said material to an extent permitted by the elastic properties of the material; and

angling the fiber end of the probe 35 to the optical waveguide, so that a part of the light signal will be taken up by the probe. The probe 35 is angled in order to tap a given light signal. If the angle is changed, another light signal is obtained in the probe.

It should be noted that the fiber end of the light conducting probe 35 is equally as wide as the optical waveguide, so as to obtain the strongest possible light signal 33. Furthermore, the probe 35 shall be manufactured from the same material as the core 30 or from a material which has an equally as high or a higher refractive index. The probe 35 may also be manufactured from a plastic fiber.

The method also enables the light conducting probe 35 to be fixed permanently to the optical waveguide, if so desired. The probe 35 is removed upon completion of a light signal tapping operation, with no residual deformation of the material at the place where the probe was inserted. When tapping light signals on light waveguide 33, no further measures need be taken to enable tapping to take place.

Another embodiment of the arrangement is illustrated in Figure 4. Figure 4 illustrates an optical fiber 1 which is comprised of a light conducting core 2 and an elastic encapsulating material 3. The refractive index of the core 2 is higher than the refractive index of the encapsulating material 3. A probe 35 is pressed into the encapsulating material 3 down towards the core 2, resulting in deformation 41 of the encapsulating material 3. When the probe 35 is pressed down to its maximum position at which its best tapping ability is obtained, a very narrow gap 42 is formed between the probe 35 and the light conducting core 30. The core 2 may, for instance, be comprised of polyimide and is encapsulated by the elastic material, which is preferably silicone rubber. Because the material is elastic, the probe 35 can be inserted into the encapsulating material 3 and tapping can commence when the probe 35 reaches the evanescence field. The tapping device can be removed, if so desired. Optical fibers extend between different telephone stations or, for instance, between different computers. The distances concerned may be large and it is necessary at times

to go into the fibers and ascertain their traffic status. In the illustrated embodiment, the optical waveguide is not secured to a substrate, but is a free lying optical fiber 1.

The method applied to tap light signals from light waveguides 23 can also be used to tap light signal from optical fibers. When tapping signals from optical fibers, the fiber must be placed on a hard supporting surface prior to the first method step, in order for tapping to take place. When the optical fiber is unduly flexible, it is not possible to insert a probe onto the fiber, unless the fiber rests on a hard supporting surface.

Another advantage afforded by the use of an elastic encapsulating material, is that a probe can be pressed down into the material and light signals tapped. Another advantage is that optical waveguides according to the aforedescribed embodiment can be manufactured cheaply and simply. The method enables light signals to be tapped from optical waveguides on temporary occasions.

It will be understood that the invention is not restricted to the aforedescribed and illustrated embodiments thereof and that modifications can be made within the scope of the following claims.

CLAIMS

1. A method of tapping light signals from an evanescence field surrounding an optical waveguide which is encapsulated with cladding, with the aid of a light conducting probe which includes an optical fiber having a free fiber end, wherein tapping of the light signals is effected without removing encapsulating material or without breaking the optical waveguide, and wherein tapping is effected with minimized damping losses, c h a r a c t e r i z e d by the steps of inserting the fiber end of the light conducting probe down towards the encapsulated optical waveguide; pressing the fiber end of the light conducting probe into the encapsulating material while elastically deforming said material to the extent permitted by the mechanical properties thereof; and angling the fiber end of the light conducting probe to the optical waveguide so that a part of the light signal present in the waveguide is taken up in the probe.

2. A method of tapping light by means of a light conducting probe according to Claim 1, c h a r a c t e r i z e d in that the probe is equally as wide as the optical waveguide, so as to obtain the best possible tapping result.

3. A method of tapping light by means of a light conducting probe in accordance with Claim 1 or 2, c h a r a c t e r i z e d in that the probe is manufactured from the same material as the light conducting core of the waveguide, or a material which has an equally as high or higher refractive index.

4. A method for tapping light by means of a light conducting probe according to Claim 1, 2 or 3, c h a r a c t e r i z e d in that the light conducting probe is fixed permanently on the optical waveguide.

5. A method of tapping light by means of a light conducting probe according to any one of the preceding claims, in which the waveguide is an optical fiber, c h a r a c t e r i z e d by placing

the optical fiber on a hard supporting surface in a first method step, prior to the light tapping operation.

6. A method of tapping light signals, substantially as herein described with reference to Figures 1-3 or Figure 4 of the accompanying drawings.

Patents Act 1977
E miner's report to the Comptroller under Section 17 (The Search Report)

Application number

GB 9307404.5

Relevant Technical fields

(i) UK Cl (Edition L) G2J (JGDB JGEC)

(ii) Int Cl (Edition 5) G02B

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

R E HARDY

Date of Search

21 MAY 1993

Documents considered relevant following a search in respect of claims ALL

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
X	GB 2215079 A (STC) See the Figures	Claim at least
X	EP 0371675 A2 (ATT) See Figure 6	Claim at least
X	US 4950046 A (HUGHES) Column 3 line 30 onwards	Claim at least

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

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